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ADVANCES IN WASTEWATER TREATMENT, PILOT PLANT, POMONA, CALIFORNIA

Federal Water Quality Administration
Cincinnati, Ohio

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ADVANCES IN WASTEWATER TREATMENT

PILOT PLANT, POMONA, CALIF.

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER QUALITY ADMINISTRATION

COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY

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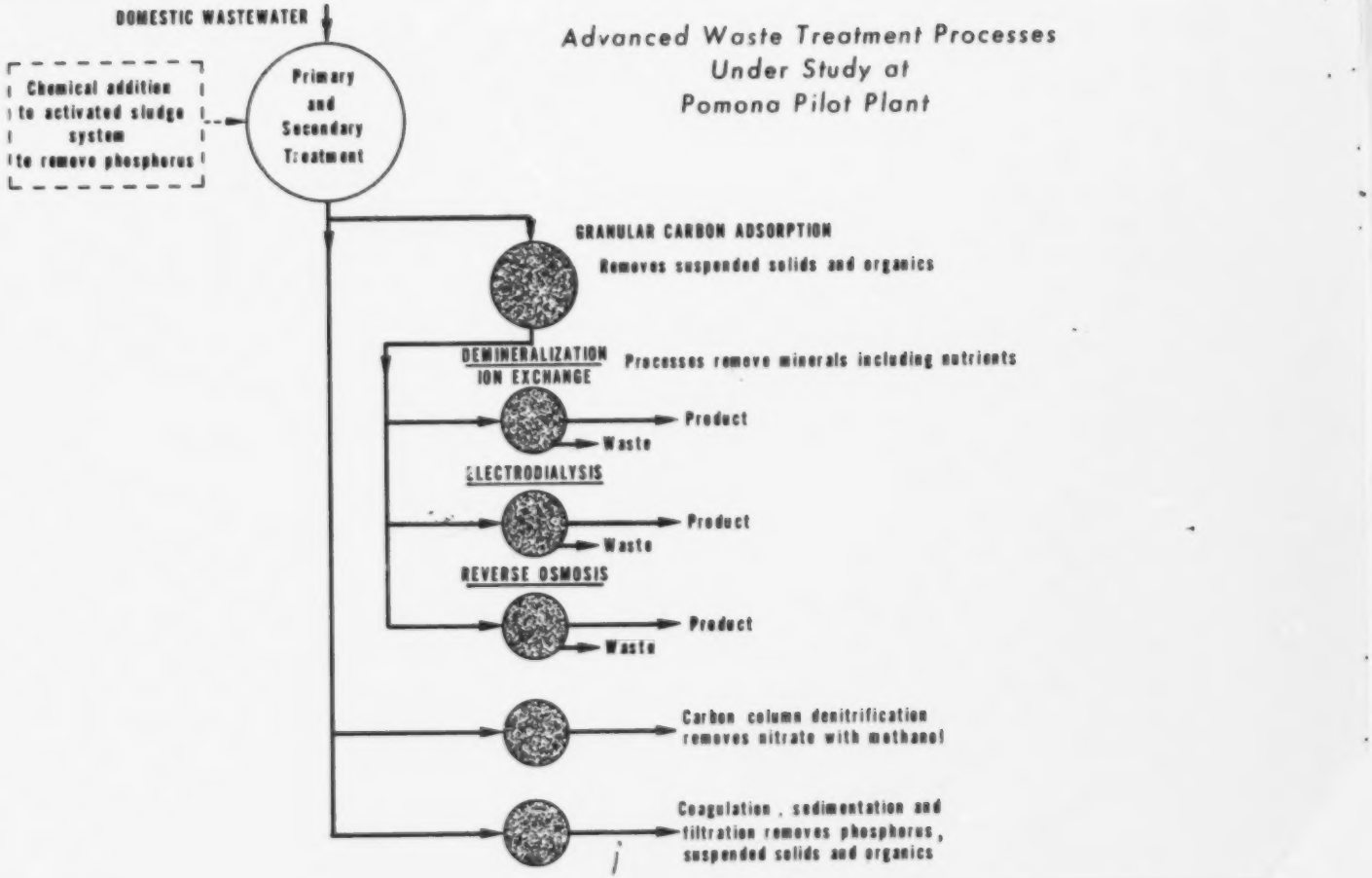
DOMESTIC WASTEWATER
Chemical addition to activated sludge system to remove phosphorus
Primary and Secondary Treatment
Advanced Waste Treatment Processes Under Study at Pomona Pilot Plant
GRANULAR CARBON ADSORPTION
Removes suspended solids and organics
DEMINERALIZATION ION EXCHANGE
Processes remove minerals including nutrients
Product
Waste
ELECTRODIALYSIS
Product
Waste
REVERSE OSMOSIS
Product
Waste
Carbon column denitrification removes nitrate with methanol
Coagulation, sedimentation and filtration removes phosphorus, suspended solids and organics

FOREWORD

Finding efficient and economically feasible ways to reduce pollution and make used water reusable poses one of today's great challenges in natural resource management and conservation.

Because of our extraordinary growth in population, industry, and irrigated agriculture, our standards of sanitation, our increased urbanization, and our ever-growing demands for fishing, swimming, boating, and other forms of water-oriented recreation, water use is increasing at a tremendous rate. At the same time, our rainfall remains relatively fixed. Unless we find new and better ways of reducing pollution and renovating wastewater, we face the potential of having a water-limited economy.

During the past 40 years, the population of the United States had doubled and its industrial production has grown about five times. For most cities we still rely on a physical settling process known as primary treatment and a microbiological process known as secondary treatment to prevent pollution of our waterways. These processes, though they have served us well in the past, can no longer cope with the quantity and complexity of the organic wastes that are discharged into our environment.

One obvious solution is to treat our water in such a way that each gallon can be reused more easily than now. Of the 150 gallons of water used daily by the average city dweller, 120 gallons return contaminated to the sewers—a flood of more than 15 billion gallons a day for the United States as a whole. If cleaned up, it would provide enough water for the daily needs of half our entire population. The flow of waste from industry and agriculture swells the total to approximately 260 billion gallons a day—equal to 70 percent of the Nation's present water needs.

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The reuse of water even now is nothing new. Many communities draw their water supplies from water courses that contain waste discharges from cities upstream. Along the Mississippi and Missouri Rivers, it is a rare community indeed that enjoys water not previously used, at least in part, by an upstream neighbor. If we consider usage for agricultural, recreational, and other miscellaneous purposes, we must accept the fact that nearly all surface and underground water has had some previous use.

Thus, although the deliberate reuse of treated wastewaters may be a startling concept to the average citizen, this practice, in varying degrees, is already widespread and is gaining momentum as our burgeoning population demands more and more water for more and more uses.

Water renovation resolves itself into a matter of finding faster and more effective processes for removing all types of wastes from water at a price that will be economically feasible.

The Advanced Waste Treatment Research Laboratory of the Federal Water Quality Administration, U. S. Department of the Interior, as one of its functions, is developing engineering, operating and design criteria for actual use of the wastewater treatment processes it has found most promising. This function is carried out, in part, by the Municipal Treatment Research Program of the Advanced Waste Treatment Research Laboratory, based in Cincinnati, Ohio. The Program is testing various processes at rates of 1 to 200 gallons per minute at several pilot plants throughout the country.

In addition to developing further information on those processes that look promising in the laboratory, the pilot plants provide engineers and technicians an opportunity to develop proficiency in the advanced treatment processes and afford the water pollution control profession and the general public an on-site observation of the dramatic improvement in water quality effected by these processes.

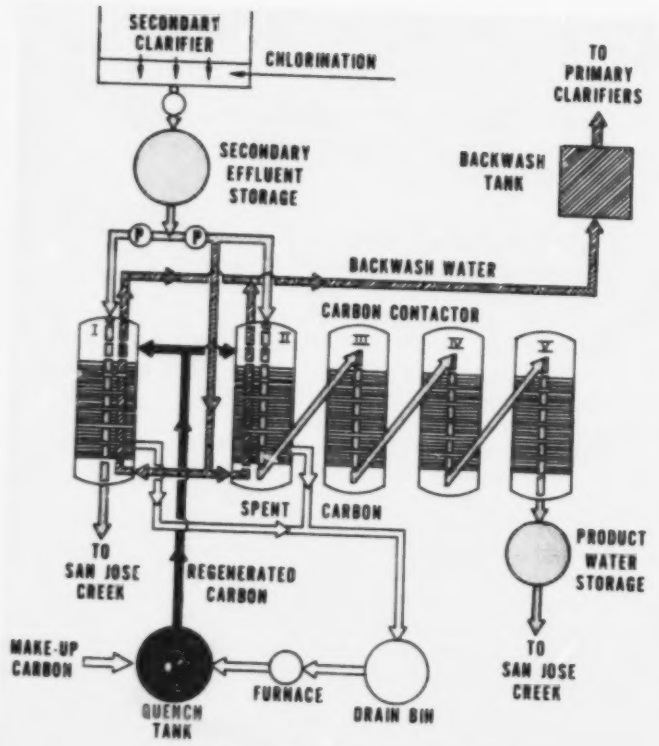
At present, four such pilot plants are in operation, all at municipal sewage treatment plants where local officials are cooperating in this research and development venture. These are located at Pomona, California; Washington, D. C.; Lebanon, Ohio; and Manassas, Virginia.

ADVANCED WASTE TREATMENT FACILITY AT POMONA, CALIF.

In 1963, the Federal Water Quality Administration and the County Sanitation Districts of Los Angeles County agreed to cooperate in the funding and staffing of pilot plant facilities on the grounds of the Pomona Water Renovation Plant. The pilot plant receives a portion of the effluent from the conventional biological facilities and investigates processes and combinations of processes to improve the quality of the water. The Sanitation Districts are particularly interested in advanced waste treatment processes which will produce reusable water.

The Pomona Water Renovation Plant provides conventional primary sedimentation and activated sludge treatment to approximately 10 million gallons per day (mgd) of wastewater originating in the City of Pomona and surrounding communities. The final effluent from this well-run plant contains 10 milligrams per liter (mg/1) of suspended solids, 5 mg/1 of biochemical oxygen demanding materials (BOD), 45 mg/1 of chemical oxygen demanding materials (COD), and 600-700 mg/1 of dissolved salts.

The initial effort at the Pomona Advanced Waste Treatment Pilot Plant was directed toward developing technical and economic information on the granular carbon adsorption process for removing the dissolved organic contaminants (as measured by COD) remaining in the conventionally-treated wastewaters. This project has progressed to the point where relatively firm economic estimates can be made. Work on various modifications of the granular carbon adsorption process is continuing and the investigation of several other processes has been undertaken. In addition to carbon adsorption, the Pomona staff is working on ion exchange, electrodialysis, reverse osmosis, mineral addition to conventional processes to enhance phosphorus removal and biological denitrification.



CARBON ADSORPTION PILOT PLANT SCHEMATIC FLOW DIAGRAM

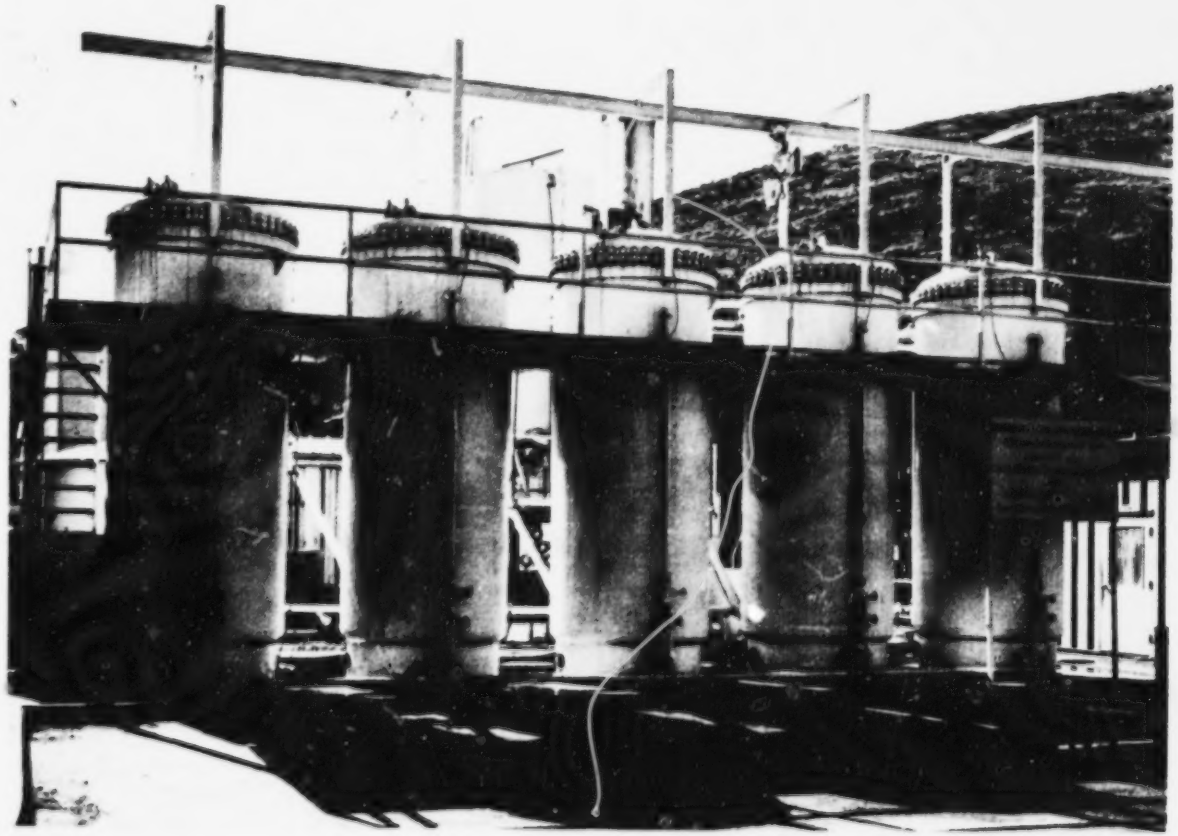
GRANULAR CARBON ADSORPTION

When normal biological waste treatment methods are used to remove organic matter from wastewater, a fraction of this organic matter is resistant to biological degradation and is, therefore, present in a treatment plant effluent. Activated carbon treatment is used to remove these "refractory" materials.

Granular activated carbon is a very porous material having a high surface area per unit volume and high adsorptive capacity for soluble organic matter.

The carbon-water contacting system consists of five steel columns (6 ft. in diameter and 16 ft. high) each containing 9-1/2 ft. of granular activated carbon. Four of these contactors are operated in series, treating 200 gallons per minute (0.3 mgd) of secondary effluent. This carbon treatment removes about 80% of the COD and virtually all of the suspended solids, color, and odor from the water.

The secondary effluent receives no pre-treatment before being applied to the carbon column and the first contactor in the series acts as a filter to remove suspended matter in

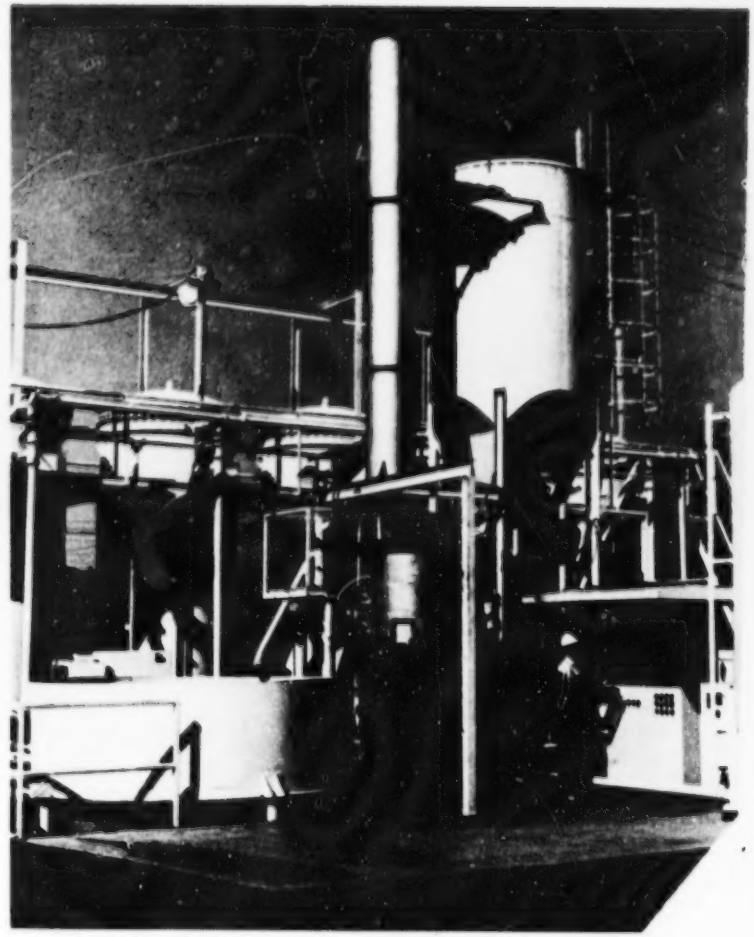


Four of the five 16-foot high contactors are operated in series and process nearly a third of a million gallons of wastewater a day.

the feed. This requires daily backwashing to prevent excessive head losses in this lead contactor.

To keep the cost of the carbon adsorption process at a reasonable level, exhausted or "used" carbon must be regenerated. The exhausted carbon is transferred hydraulically to a drain bin, regenerated thermally in a six-hearth furnace at a maximum temperature of 1700°F, quenched, and hydraulically transferred back into the contactor. In the pass through the furnace, the adsorbed organic matter is burned off, restoring the porosity and adsorptive capacity of the carbon granules.

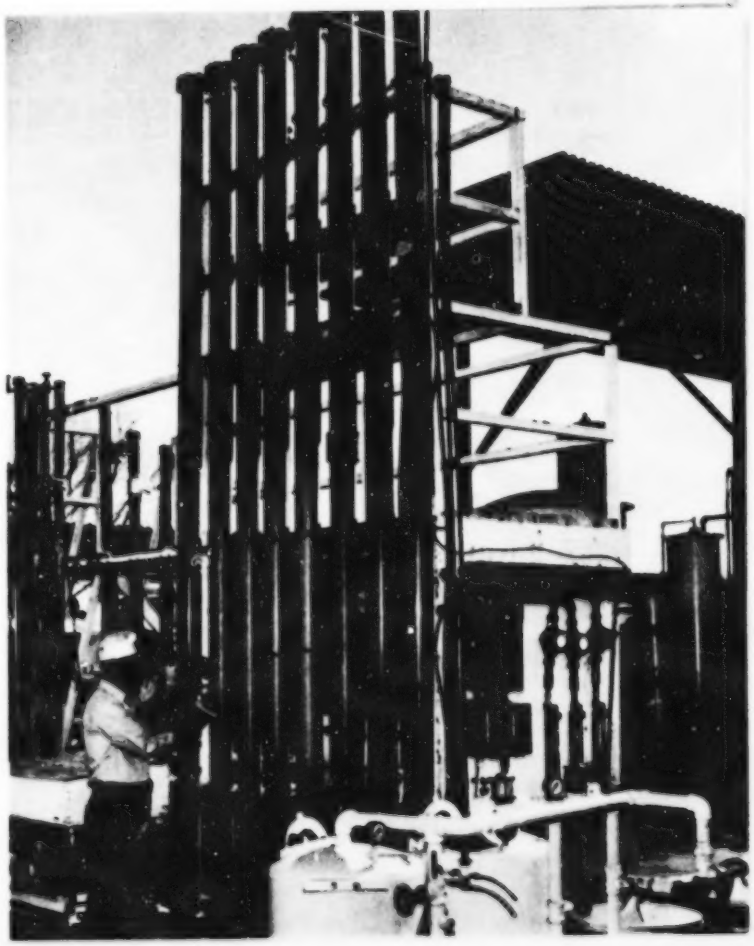
Operation of the pilot plant has shown that the carbon adsorption process can produce water of high



200 gpm granular carbon adsoprtion system. Three of the five contactors can be seen to the left. The other major pieces of equipment in front of the contactors are, from right to left, the furnace control panel, the spent carbon drain bin, the 6-hearth furnace and the quench tank.

quality suitable for many reuse applications. The total cost of granular carbon adsorption for renovation of wastewater is estimated at nine cents per thousand gallons for a plant having a daily capacity of 10 million gallons.

Small-scale carbon studies are conducted in two-inch and four-inch diameter columns. These columns have been used for several satellite studies including investigation of surface loading rate, biological denitrification on carbon and sand, and comparison of carbons from various manufacturers. Small-scale operation permits optimizing a column process prior to evaluation at a larger, more expensive scale.



These small-scale satellite columns have been used to extend information on carbon adsorption and biological denitrification.

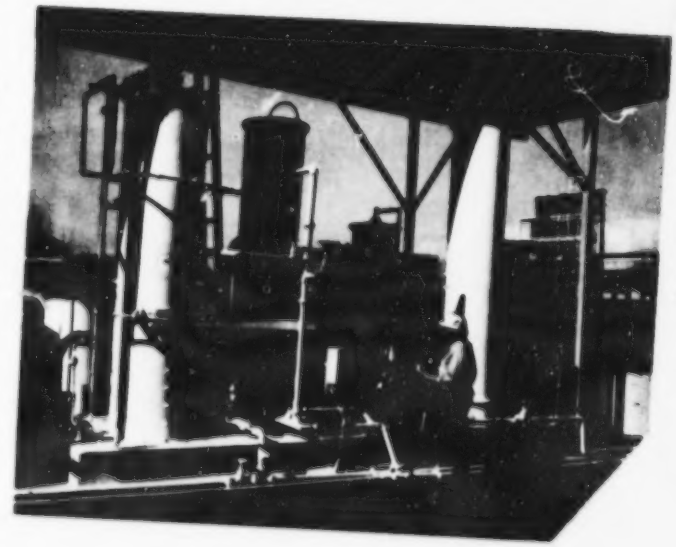
DEMINERALIZATION PROCESSES

Since the dissolved mineral content of a water is increased by 300-400 mg/1 during each use, the treatment of the resulting wastewater for reuse as a potable supply may require demineralization. Removal of this added increment during treatment will be necessary to prevent excessive buildup of these mineral salts unless this buildup can be prevented by the addition of a low mineral make-up water. Three processes are being evaluated to separate the excess salts from wastewater; these are ion exchange, electrodialysis and reverse osmosis.

— Ion Exchange —

Ion exchange is a proven method for softening or demineralizing water. Many natural materials, as well as an increasing number of synthetic materials, have the ability to exchange minerals or ions from an aqueous solution for ions in the material itself.

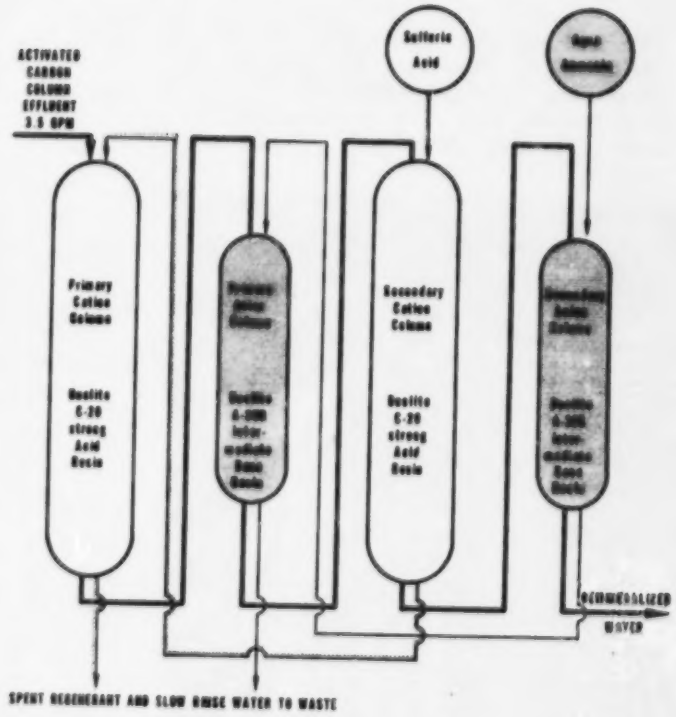
As a result of great improvement in the physical, chemical and operational characteristics of the synthetic cation and anion resins, ion exchange is becoming a potentially economical demineralization process to treat brackish water and to renovate wastewater effluents as sources of water for domestic, agricultural and industrial uses.



5000 gpd ion exchange unit. Shown are two cation exchange columns, a granular carbon adsorption column, a high solids chemical contactor-clarifier and control panel.

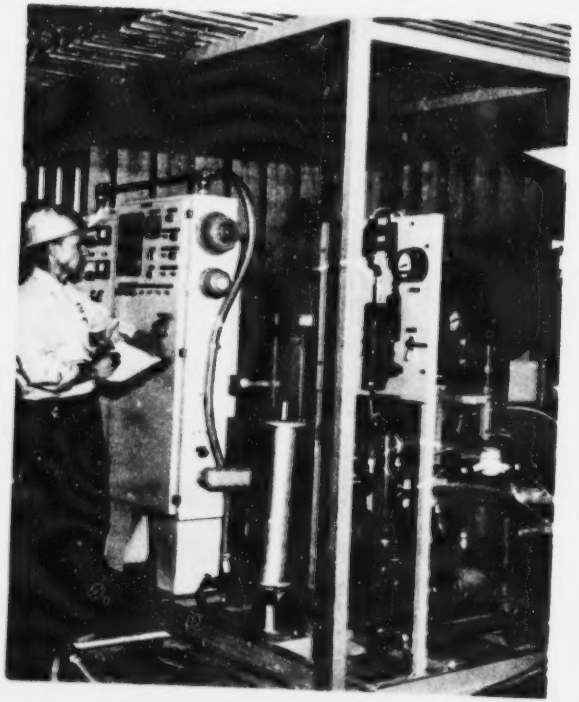
The ion exchange process has been investigated at Pomona since mid-1967 at the 5000 gallon per day (gpd) scale. This process utilizes carbon-treated secondary effluent as feed and consists of four columns in series as illustrated by the accompanying flow diagram and picture. Flow passage through the exchangers during demineralization is in a downward direction. The resins are regenerated by applying the regenerant solutions in a downflow direction first to the secondary unit then to the primary unit for both the cation and anion cycles. The cation exchangers are regenerated with sulfuric acid while the anion resins are regenerated with ammonia.

The estimated cost to achieve 90% demineralization of wastewater (exclusive of pretreatment and regenerant brine disposal) is 25¢ per thousand gallons at the 10 million gallon per day scale. The renovated water from the ion exchange process, after chlorination, meets drinking water standards. If a greater concentration of dissolved solids were required for palatability, this water could be blended with another potable source as required, thus reducing the cost to the consumer. In addition to preventing buildup of total minerals in reused wastewater, significant quantities of algae nutrients such as phosphorus and nitrogen compounds are removed by ion exchange.



FLOW DIAGRAM OF ION EXCHANGE PROCESS

The electrodialysis membrane stack is obscured by the maze of filters, pumps and piping necessary in this experimental unit. The operator is taking readings from the control panel.

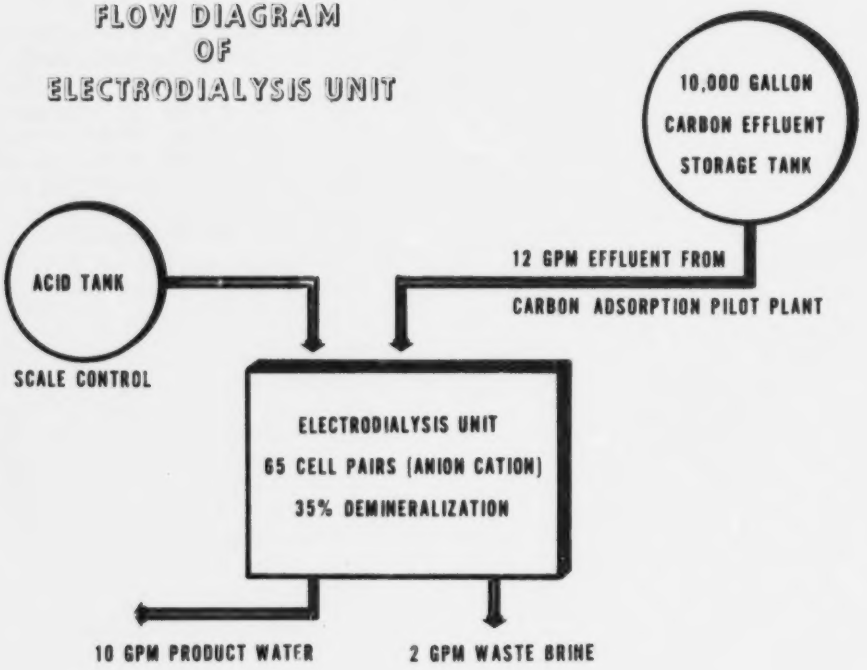


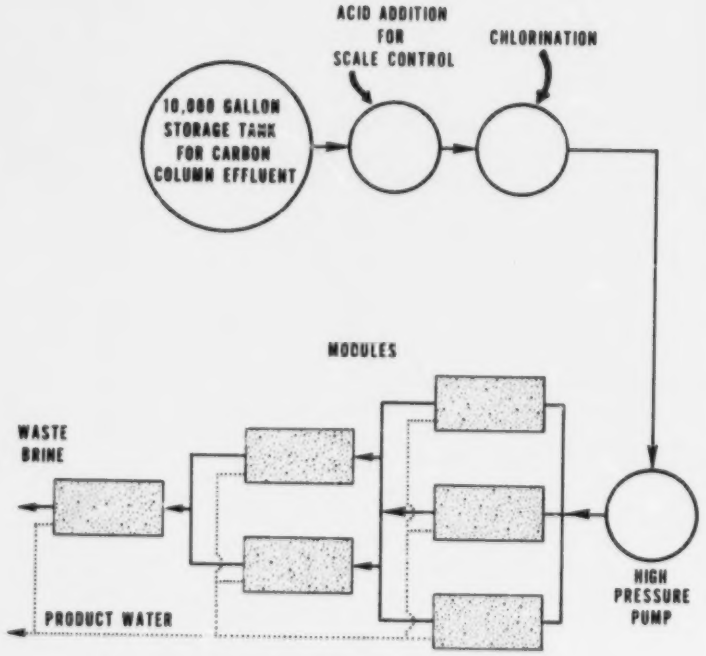
Electrodialysis

An electric potential impressed across a cell containing mineralized water will cause positively charged ions (cations) to migrate to the negative electrode and negatively charged ions (anions) to migrate to the positive electrode. If cation and anion permeable membranes are placed alternately between the electrodes, alternate compartments become more concentrated while the intervening compartments become diluted. This separation process is called electrodialysis, and is being used to produce potable water by partially demineralizing brackish ground water in several water-short areas of the world. Application of this process for the partial demineralization of wastewater is currently under investigation to determine the effect of materials such as organics, which are common to wastewater but not normally found in brackish water.

The electrodialysis process at Pomona receives 12 gallons per minute (gpm) of carbon-treated secondary effluent as the feed stream and produces 10 gpm of 35% demineralized product water and 2 gpm of waste brine. Anticipated cost of this process (exclusive of carbon adsorption and brine disposal) is estimated to be 17 cents per 1000 gallons at the 10 mgd scale. Since only 35% of the minerals are removed, the potential for cost reduction by blending is less significant than with ion exhange.

FLOW DIAGRAM OF ELECTRODIALYSIS UNIT





Tapered Module Design for Tubular or Spiral Wound Modules

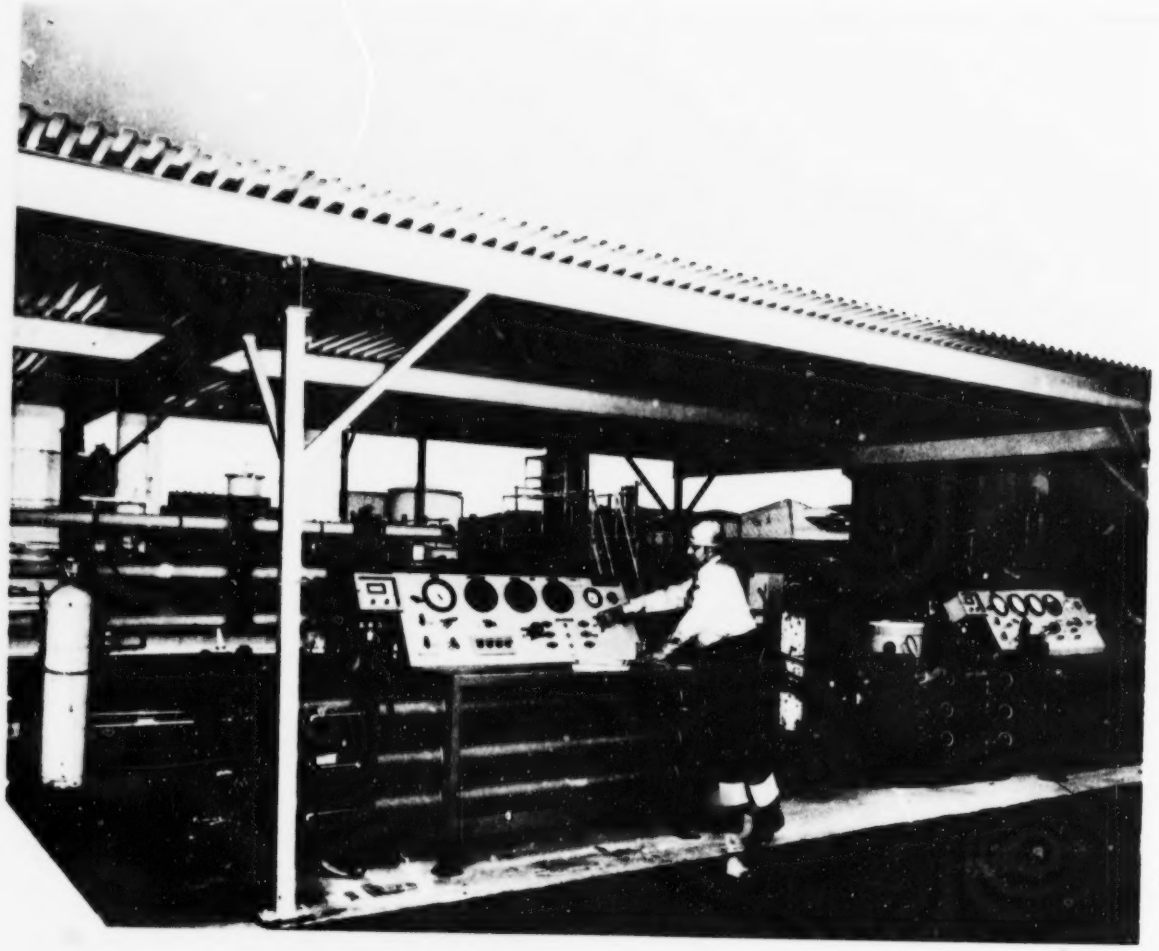
REVERSE OSMOSIS
FLOW DIAGRAM

– Reverse Osmosis –

Reverse osmosis, a membrane separation process, has emerged during the last decade as a competing process for the separation of both organic and inorganic solutes from a variety of sources including brackish, industrial, and wastewater streams. The reason for the increasing interest in the process is the simplicity, high product quality and the low treatment cost that could result from further development work. Although reverse osmosis is usually considered a demineralization process, it also has the demonstrated capacity of removing soluble organic species as well as the troublesome nutrients, nitrogen and phosphorus.

Reverse osmosis derives its name from the fact that water is caused to pass from a solution of high concentration of minerals through a semi-permeable membrane (usually cellulose acetate) to a solution of low mineral concentration—just the opposite of natural osmosis. To cause this flow, a pressure greater than the osmotic pressure must be applied to the more concentrated solution.

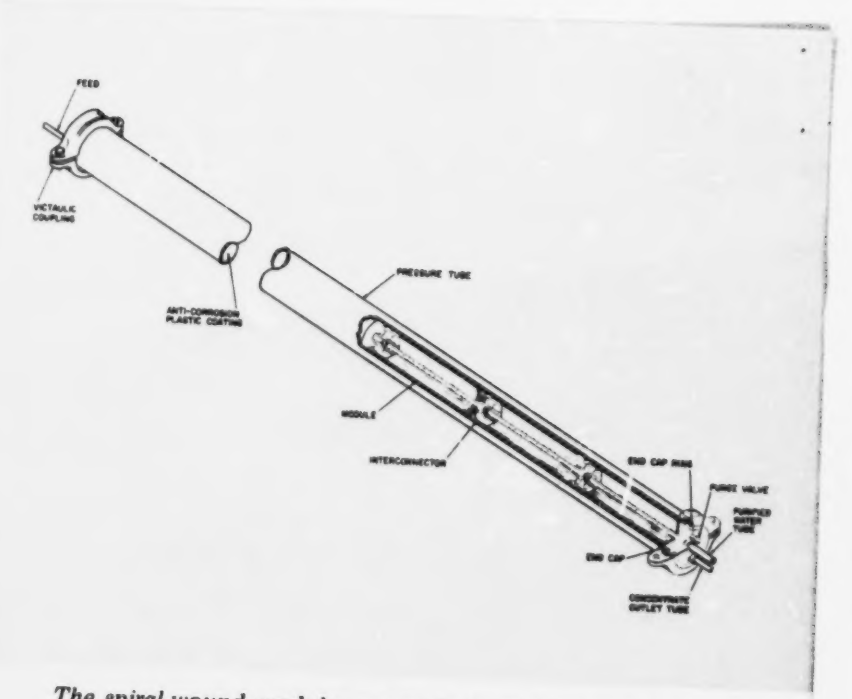
Two types of reverse osmosis units are presently being evaluated at Pomona. The first unit employs spiral-wound cellulose acetate modules enclosed in 4-inch diameter steel pipes. This spiral-wound unit is designed for 10,000 gpd of product water with 90%



A 5000 gpd spiral-wound reverse osmosis unit. Two identical units are shown in the foreground. These were operated in parallel to determine the effect of pre-treatment and other variables on production rate and product quality. The 10,000 gpd spiral- wound unit can be seen in the background.

demineralization and 75% recovery of the feedwater as product. Pressures of 600 pounds per square inch (psi) are developed and force the feedwater through this cellulose acetate membrane at 10 to 15 gpd/ft^2 leaving the concentrated brine.

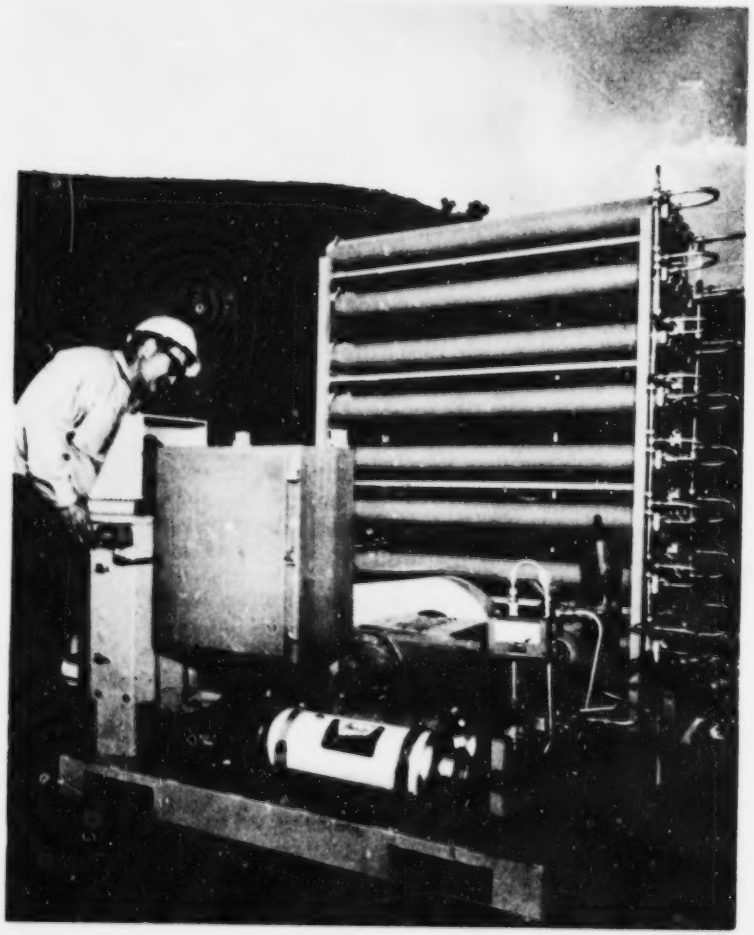
The second type of reverse osmosis system employs the tubular module that contains the membrane on the inside of a 1/2-inch diameter tube. In this unit, feedwater flows axially within the tubes and the product water collects in a shell that surrounds groups of the inter-connected tubes. This unit produces 5000 gpd of product while achieving



The spiral-wound modules are made to fit inside of a 4 inch pipe or pressure tube. These tubes can then be interconnected to form larger modular units of any desired size.

90-95% demineralization at 75% recovery of the feed as product.

Much remains to be learned about the treatment of wastewater by reverse osmosis. Preliminary costs of 42 cents per 1000 gallons (exclusive of any necessary pretreatment and of brine disposal) are anticipated for a product water with 90% of the dissolved solids removed. Algae nutrients such as nitrogen and phosphorus are likewise removed, leaving a product water low in materials that could cause excessive growths of nuisance organisms. This water, after chlorination, would be suitable for domestic use.



A 5000 gpd tubular reverse osmosis unit. Each 4" diameter pipe contains eighteen 1/2" diameter tubes lined on the inside with a cellulose acetate membrane. Within each pipe, all tubes are connected in series.

NUTRIENT REMOVAL

Certain materials in wastewater act as nutrients for algae and other aquatic plants in receiving waters, causing excessive growths of these organisms. These excessive growths are an esthetic nuisance and cause depletion of oxygen to a degree that can result in fish kills.

— Phosphorus —

One of the most important algal nutrients found in wastewater is phosphorus. The chemical removal of phosphorus has been studied at a 1.5 mgd scale in a secondary treatment system by adding aluminum compounds to the aeration tanks. Reduction of total phosphorus from 12 mg/1 to 0.5 mg/1 as P in the secondary plant at a ratio of aluminum to phosphorus of 2 to 1 was accomplished. Chemical costs of 6 cents per 1000 gallons are anticipated for this treatment scheme.

In addition to phosphorus removal in the secondary treatment system, removal can also be accomplished in a tertiary treatment system. Utilizing a lime coagulation, settling, and sand filtration system at a flow rate of 7200 gpd, the phosphorus concentration of secondary effluent was reduced from 10 mg/1 to 0.2 mg/1 at a total estimated cost of 8 cents per 1000 gallons at a 10 mgd scale.

— Nitrogen —

The nitrate ion is another important nutrient that can accelerate biological growths in receiving waters and cause secondary pollution.

Extensive work has shown that efficient biological denitrification (reduction of the nitrate ion to nitrogen gas) can be promoted on granular carbon or sand in columns at hydraulic detention times of less than 10 minutes by the addition of methanol to the column influent. The removal of nitrate is primarily a function of the amount of methanol available to the biological system as an energy source. For an additional chemical cost of 1.6 cents per 1000 gallons, 20 mg/1 of nitrate nitrogen can be reduced to less than 1 mg/1 in the first stage of a four-stage granular carbon column operation similar to that described earlier.

LABORATORY FACILITIES

The building that houses the laboratory at Pomona covers 1000 square feet and is equipped with the necessary instrumentation and chemical supplies to conduct a broad range of chemical analyses. The chemistry staff is trained in all special techniques used in sanitary chemistry. All water samples from the various processes under study are brought into this laboratory daily for analysis. Samples of sludges and carbon are analyzed on a less frequent basis.

PHYSICAL PLANT & STAFF

The Pomona Pilot Plant is staffed by 15 specialists—sanitary and chemical engineers, chemists and technicians—from both the Federal Water Quality Administration and the County Sanitation Districts of Los Angeles County. The total area encompassed is 13,000 square feet, 1600 square feet of which is laboratory, office and storage space. The mild climate of the Los Angeles area permits location of the process equipment outdoors. Construction of the carbon adsorption plant and laboratory was completed in 1965. The reverse osmosis and ion exchange units were placed in operation in 1966 and 1967, respectively, followed by the electrodialysis unit in 1968.

The laboratory, chemists and engineers must perform a wide variety of daily tests to determine process efficiencies.

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